AN EVALUATION OF TREE MORTALITY IN FOUR CEDAR GROVE CAMPGROUNDS, KINGS CANYON NATIONAL PARK

Report no. 83-09

FOREST PEST MANAGEMENT USDA FOREST SERVICE
PACIFIC SOUTHWEST REGION

FOREST PEST MANAGEMENT
Pacific Southwest Region

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ABSTRACT

The causes of tree death during a one-year period were determined at four Cedar Grove Campgrounds. The kinds of pests and patterns of mortality observed were similar to those normally found throughout much of the Sierra Nevada. During the evaluation period 50 trees died in an area of 116 acres. The major pests present included various combinations of bark beetles, root diseases and dwarf mistletoes. Competition for moisture and nutrients due to overstocked plant aggregations was also judged to play a significant role in predisposing trees to bark beetle attacks. Without any vegetation or pest management activites, similar mortality will continue to occur.

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INTRODUCTION

The Cedar Grove area in Sequoia and Kings Canyon National Parks is 65 miles east of Fresno and from west to east, includes the following four campgrounds: Sheep Creek (Camp 1), Sentinel (Camp 2), Canyon View (Camp 3), and Moraine (Camp 4). The campgrounds are all adjacent to the South Fork of the Kings River at an elevation of about 4,600 feet, and contain 359 camping sites including four group sites. These four campgrounds are normally open between May and October and during the 1981 season visitor use totalled 24,025.

The forest vegetation in Sheep Creek and Sentinel Camps is predominantly young growth mixed conifer type with scattered old growth trees. Moving east and up river, Canyon View and Moraine Camps have much drier soils and vegetation shifts to predominantly ponderosa and Jeffrey pine. All of the campgrounds have areas with well-stocked vigorously growing trees as well as areas with densely stocked overstory trees and/or densely stocked understory saplings and poles.

PAST PEST MANAGEMENT

Until 1981, there had been an annual insect control program of removing dead and dying bark beetle infested pines from Cedar Grove. Earlier efforts included using insecticide sprays to prevent bark beetle emergence from killed trees. The effectiveness of this procedure in preventing future insect-caused mortality was questioned, and the use of insecticides was eventually stopped.

A comprehensive view of the mortality situation recognizes that there are causes of tree deaths at Cedar Grove other than bark beetles. The dwarf mistletoe situation in Canyon View and Moraine Camps was serious enough in 1967 to warrant a suppression project. In 1977 Forest Pest Management personnel identified *Fomes annosus* root disease in incense cedar and ponderosa pine and true mistletoe in incense cedar as disease pests in the area. Regardless of specific causes, additional trees have died year after year at Cedar Grove.

The primary objectives of this evaluation, as requested by the National Park Service, were to (1) identify and charactize the causes of all tree mortality during a one-year period, and (2) to develop management alternatives that would reduce these losses.

SURVEY PROCEDURES

All trees in the four campgrounds that died between spring 1980 and spring 1981 were visited. Above and below ground portions of each dead tree were examined for pests. Information collected at each mortality spot included dead tree species, stand type, basal area, site index, and pest ratings (see sample data sheet, page 11). Also the location of each dead tree and root disease center was placed on campground maps (Appendix A).

INTRODUCTION

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RESULTS AND DISCUSSION

Fifty trees died in 32 mortality groups during the 1-year evaluation period. A variety of pests were found associated with tree mortality as shown below in Table 1. The biologies of these pests are discussed in Appendix B.

Table 1. Pests associated with tree mortality at Cedar Grove and their hosts, Spring 1980 - Spring 1981.

	Pest	Cedar Grove Hosts
Insects:	Western pine beetle (_Dendroctonus brevicomis_)	Ponderosa pine
	Jeffrey pine beetle (_D. Jeffreyi_)	Jeffrey pine
	Fir engraver (_Scolytus ventralis_)	White fir
	California flatheaded borer (_Melanophila californica_)	All pines
	Red turpentine beetle (_D. valens_)	All pines
	Cedar bark beetles (_Phleosinus_ spp.)	Incense-cedar
	Mountain pine beetle (_D. ponderosae_)	Ponderosa & sugar pine
Diseases:	Dwarf mistletoes (_Arceuthobium_ spp.)	All pines
	Annosus root disease (_Fomes annosus_)	All pines
	True mistletoe (_Phoradendron juniperinum_ ssp. _libocedri_)	Incense-cedar
Injuries:	Mechanical	All species

The pest or pest complexes that were found associated with mortality groups are listed in Table 2. Bark beetles alone were by far the most frequently encountered pests, and at only two mortality spots were no insects found. Dwarf mistletoe and root rots accounted for almost all of the disease-associated tree death.

Table 2. Pest complexes found associated with tree mortality groups at Cedar Grove campgrounds.

Pest Complex	Number of Mortality Groups
Bark beetles only	21
Dwarf mistletoe & bark beetles	6
Root disease only	2
Mechanical injury & bark beetles	2
Dwarf mistletoe, root disease & bark beetles	1
TOTAL	32

Tables 3 and 4 below summarize tree mortality by campground and tree species. The majority of mortality was found in Canyon View and Morraine campgrounds which are generally drier sites (Table 3). Ponderosa pine, which is the predominent tree species at Cedar Grove, accounted for most of the dead trees with mortality among the other conifers being roughly equal (Table 4).

Table 3. Tree mortality at four Cedar Grove campgrounds, Spring 1980 - Spring 1981.

Campground	No. Dead Trees	Percent
Sheep Creek (1)	11	22
Sentinel (2)	3	6
Canyon View (3)	17	34
Moraine (4)	19	38
TOTAL	50	100

Table 4. Mortality of tree species in Cedar Grove campgrounds, Spring 1980 - Spring 1981.

Species	Number Dead	Percent
Ponderosa pine	31	62
Jeffrey pine	8	16
White fir	5	10
Incense-cedar	4	8
Sugar pine	2	4
TOTAL	50	100

The 50 trees that died in the four campgrounds represents an average annual mortality rate of 0.43 trees/acre. Results from numerous large scale surveys throughout northern California forests indicate that tree mortality during years with "normal"[1/] precipitation ranges between 0.1 and 0.3 trees/acre/year and up to 1.0 trees/acre/year during periods of severe drought. A high level of tree mortality associated predominantly with bark beetles most often indicates that trees are under stress from predisposing factors. Moisture stress caused by below normal precipitation, overstocking, or poor soils (or any combination of these) is common in California.

Precipitation records for Grant Grove between 1976 and 1982 were examined. Grant Grove is nearly 2,000 feet higher than Cedar Grove and is 17 miles to the southwest. Absolute amounts of precipitation received at each location are undoubtedly different, but the pattern is probably similar. The long term average amount of precipitation received at a location is one of the factors that governs forest type. Annual fluctuations around the average usually have an impact on the amount of tree mortality.

Lower than normal precipitation during late 1978 and early 1979 (Table 5) probably caused trees to undergo moisture stress earlier than usual in 1979. Stress early in the season would allow more successful attacks and a greater potential for damage by the California flatheaded borer and red turpentine beetle. A few trees would have been killed outright and would have faded in late 1979 or the spring of 1980. The feeding damage caused by the California flatheaded borer and red turpentine beetle would have caused trees to become more susceptible to the attacks by pine bark beetles.

[1/] Normal refers to the long-term (30 years) average for a site.

Table 5. Precipitation* - monthly normal and departures from normal - in inches, for Grant Grove, Kings Canyon National Park, 1976-1982.

	MONTH												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
76	- 7.7	- 1.6	-3.4	-1.8	-1.0	-0.3	+0.2	+0.5	+4.3	-0.2	-4.9	-6.3	-22.2
77	- 5.0	- 5.5	-4.9	-4.8	+2.2	+0.5	0.0	+0.4	-0.5	-0.8	-2.3	+6.7	-14.1
78	+ 5.7	+ 6.3	+5.6	+3.2	-1.5	-0.4	0.0	0.0	+5.2	-1.5**	-2.5	-3.4	+16.8
79	- 1.4	+ 3.8	+0.9	-4.7	-0.5	-0.4	+0.1	-0.1	-0.4	+1.5	-2.7	-4.0	- 7.9
80	+17.1	+11.6	-1.1	-2.4	+0.7	-0.2	-0.1	-0.1	-0.4	-0.4	-4.8	-3.8	+16.2
81	+ 3.0	- 4.8	+1.2	-3.0	+1.2	-0.4	-0.1	-0.1	-0.5	+3.0	+0.3	-3.2	- 3.2
82	+ 4.7	- 2.7	+8.0	+6.8	-0.6	+1.0	+0.1	-0.1	+7.5	+4.9	+6.6	+3.5	+39.9
NORMAL:***	7.8	7.2	6.8	4.8	1.6	0.4	0.1	0.1	0.5	1.5	5.1	7.6	43.5

* Precipitation data as published by the National Oceanic and Atmospheric Administration; Asheville, N.C.

** Underlined numbers are precipitation deficits that could have contributed to Spring 1980 - Spring 1981 tree mortality.

*** Normal monthly precipitation is based on climatical data collected from 1941-1970.

Although the total amount of precipitation received during 1980 was far above normal, more than half the total fell during January and February. Precipitation was below normal during most of the other months that year. The extended period of moisture stress during 1980 could have contributed to the amount of bark beetle-caused mortality which occurred that year, as well as the spring of 1981.

The effects of low precipitation are compounded by site and stand conditions. Stands growing on excessively drained soil such as the glacial till in Canyon View and Moraine campgrounds would be expected to show higher mortality in response to low precipitation than stands growing on soils with greater water holding capacities.

Table 6 displays tree mortality as it occurred in tree aggregations of different site quality. The site classes are used by USDA Forest Service, Region 5 as developed by D. Dunning (1942, California Forest and Range Experiment Station Research Note No. 28). Site I indicates the best site class.

Table 6. Site class of tree aggregates with mortality at Cedar Grove campgrounds, Spring 1980 - Spring 1981.

Site Class	No. Dead Trees	Percent of Total Dead Trees
I	5	10
II	23	46
III	18	36
IV	4	8
TOTAL	50	100

Listing mortality by site class can be misleading unless the number or basal area of trees at each mortality group is considered. Too many trees occupying a given site can create competition for moisture and nutrients and produce stresses similar to those occurring during drought conditions. The Forest Service, Region 5 has developed general limits of acceptable basal area stocking for commercial timber stands of different forest type and site class. These guidelines are based on "normal" or fully stocked unmanaged stands studied back in the 1930's. A normal stand "so far as any practical consideration is involved, utilizes its site completely."[1/] Although "normal" stands contain a large volume of wood, indvidual trees may not be growing well. These stands are prone to pest problems. For

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[1/] Meyer, W.H. 1938. Yield of even-aged stands of ponderosa pine. USDA Technical Bulletin No. 630, 60 pp.

most silvicultural systems stands are kept between 55% and 90% of "normal". From the standpoint of minimizing pest problems, basal areas closer to 55% of normal are most effective. Even though these guidelines were developed for timber stands, they are appropriate for recreation areas because they define a range of tree stocking levels that favors or promotes thrifty trees.

In some situations there may be uneven aged stands that have an overstory stocked within acceptable limits and also a dense understory of seedlings too small to measure for basal area. Our survey procedure includes recording the size class and density (percent crown closure) of trees immediately around the mortality spot. The categories for describing stocking density are listed in Table 7.

Table 7. Stocking densites as measured by percent of full crown closure.

Percent Crown Closure	Stocking Density
<10	Non-stocked
10-19	Sparse
20-39	Poor
40-69	Medium
70-100	Good

The combination of an adequately stocked overstory plus a young understory with more than 70% crown closure can produce the same effect (although not as quantifiable) as high basal areas.

Mortality caused by root diseases, dwarf mistletoe and mechanical injury is not usually directly related to site quality or stocking density. Experience from drought situations, however, demonstrates that successful bark beetle attacks and subsequent mortality are often tied to stresses caused by inter-tree competition for soil moisture. Therefore, we looked at stocking densities around the 21 mortality groups that had "insect only" pest complexes. Five of these had dense seedlings understories (mainly incense-cedar) in excess of 70% crown closure in addition to an overstory stocked between 20 and 70% crown closure. Basal areas of the remaining 16 mortality spots are as follows in Table 8.

Table 8. The distribution of dead tree groups with "insect only" mortality by basal area stocking.

Basal Area (% of normal)	Number of Mortality Groups
less than 55	3
55-75	5
more than 75	8
TOTAL	16

CONCLUSIONS AND ALTERNATIVES

The causes and patterns of tree mortality at Cedar Grove are not unusual or unique, but are similar to situations encountered throughout much of the Sierra Nevada. The proportion of tree deaths attributable to bark beetles and overstocking is, however, about as high as any of our previous pest surveys have found in California. Also, tree mortality from spring 1980 to Spring 1981 on a per acre basis is at a level that could be considered slightly above normal. Lower than normal precipitation and overstocking most likely contributed to these high mortality levels.

In dealing with tree mortality at Cedar Grove, there are two alternatives to choose from: do nothing or implement a well defined vegetation management plan that includes pest conditions. The primary objective for most campgrounds is to provide an attractive setting, as close to natural as possible, that offers shade, screening and privacy in a safe environment. Such campgrounds require healthy, vigorous trees of different ages and mixed species. In these kinds of stands risks from hazardous trees and losses from pests would be minimized. Diversity of species will often reduce pest losses and create an appealing appearance. Achieving these results over an extended time is rarely possible without some degree of vegetation management.

The do nothing alternative assumes that past tree mortality trends, as documented within this report, will recur. Bark beetles will continue to attack weakened trees, especially in densely stocked aggregations. Root disease centers will enlarge and conifer reproduction will not survive for very long within the centers. Fomes annosus may create hazardous trees by decaying the structural roots of conifers. Larger root disease centers can also provide a habitat that will support high rodent populations which can increase the potential for plague outbreaks and decrease the number of plant species that could survive. Dwarf mistletoe would intensify within infected trees and spread to healthy ones resulting in low vigor trees susceptible to insect attack. Drought conditions over an extended time period, in addition to stress created by construction and mechanical injury, would accelerate mortality rates. The expected overall long term results are understocked campgrounds with large openings and very little

species diversity. Finally, as time and mortality continue, the opportunities and options available to perpetuate desirable stand characteristics will decrease.

The vegetation management alternative provides the key to dealing effectively with pests by applying integrated pest management concepts to the Resource Management program. All biological aspects of pests and their hosts should be incorporated into vegetation management strategies. Such a plan would also consider desired shading, screening, tree spacing, species diversity, age-class distribution and hazard tree policies. The information below should be a part of that plan. We realize that some of these activities are already included in the Park's normal procedures.

1. Thin overstocked tree aggregations. Proper thinning in recreation areas will provide several benefits for the residual vegetation. It can help trees maintain good growth and minimize stress. The resulting reduction in competition can increase tree resistance to bark beetle attack, and released trees with light-to-moderate dwarf mistletoe infections in the lower crown may outgrow the parasite. Whenever thinning, trees free of mistletoe should be favored as leave trees. Also, removing selected conifers will reduce root contacts between remaining trees and lower the probability of underground root disease spread.

Thinning guidelines may be developed using basal area control or spacing criteria. Either of these approaches are usable with pole-sized and larger trees. In situations involving dense understories of seedlings and saplings, however, spacing control is the most feasible. At a minimum, small trees should be thinned to levels where individual crowns do not overlap, i.e., the canopy is not fully closed. Such a thinning program for seedlings and saplings will foster full-crowned trees with good screening potential.

2. Reduce dwarf mistletoe impact. Several alternatives for controlling dwarf mistletoe are available. The procedures used most often in developed recreation sites include removing severely infected trees, pruning to eliminate all infections and removing only witches brooms. A separate Forest Pest Management biological evaluation of dwarf mistletoe at Cedar Grove was completed and sent to the Park Superintendent on June 26, 1981. That report summarized procedures for dwarf mistletoe control projects. Since then the Park inventoried frequency and intensity of dwarf mistletoe in all four campgrounds and prepared a detailed suppression proposal for Sheep Creek Campground. Mistletoe control projects were completed in 1967 in Canyon View and Moraine Campgrounds, and, as a result, the most severe mistletoe infestations are currently in Sheep Creek and Sentinel Campgrounds.

3. Treat slash to avoid pine engraver beetle (Ips) damage. Although slash is normally removed very promptly at Cedar Grove, we have included information that is appropriate for any area in the Park in the event that trees are removed, thinning takes place, or if a dwarf mistletoe project is implemented. The biology of this pest and treatment methods are included in Appendix B.

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4. Reduce root disease impact. The Park already routinely treats stumps with borax (sodium tetraborate) to prevent the initiation of new root disease centers and should continue this practice. Dealing with established centers, however, is more difficult. The following alternatives are available.

a) Stump and root removal. Removing as much stump and root material as possible will eliminate the underground means of root disease spread. After any small roots that remain in the soil have been decayed, the site will be suitable for conifer regeneration. Recently cut stumps can be pulled out, but rotten stumps will have to be removed by excavation or complete burning. The effectiveness of this method depends on how much root material is removed.

b) Stump fumigation. Root disease fungi have been eradicated from infested stumps by fumigation. This technique, however, has not been clearly demonstrated to be effective with *Fomes annosus* under California conditions. Therefore application of this procedure would have to be considered experimental.

5. Favor hardwoods. If hardwoods are given room to grow and do not have to compete with conifers, they can reduce the impact of several pests. When interspersed with conifers their crowns present a barrier to dwarf mistletoe spread, and their root systems may prevent the spread of most root diseases. Oaks are immune to *Fomes annosus* and will survive within disease centers. They also are not susceptible to any of the insects associated with tree mortality at Cedar Grove. The main drawbacks to hardwoods are that they can be infected by true mistletoes, Armillaria root disease, and as they grow larger they can become hazardous.

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PEST DAMAGE INVENTORY GROUND CHECK FORM - CEDAR GROVE

Campground ______ Township-Range ______ Date ______ Continuation No. ______

Forest Type ______ Photo Plot ID No. ______ Crew ______ Page ______ of ______

Pest Complex ______ / ______ / ______ / ______ Notes ______

STAND DATA								SITE DATA		
	Stand Class (Type)	Factor	PRISM DATA			SITE INDEX DATA				
			Live	Dead	Stump	Age	Ht.	Topo.	Aspect	%Slope
Map		20								
Ground		40								

TREE DATA (PI)			
No.	Sp.	Ht.	Class

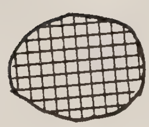
TREE DATA (GROUND)					PEST DATA (GROUND)									
No.	Sp.	DBH	Ht.	Years Dead	Sp.	Rating	Sp.	Rating	Sp.	Rating	Sp.	Rating	Sp.	Rating

APPENDIX A

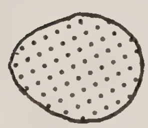
LOCATIONS OF DEAD TREES AND ROOT DISEASE CENTERS

MAP SYMBOLS:

● DEAD TREE



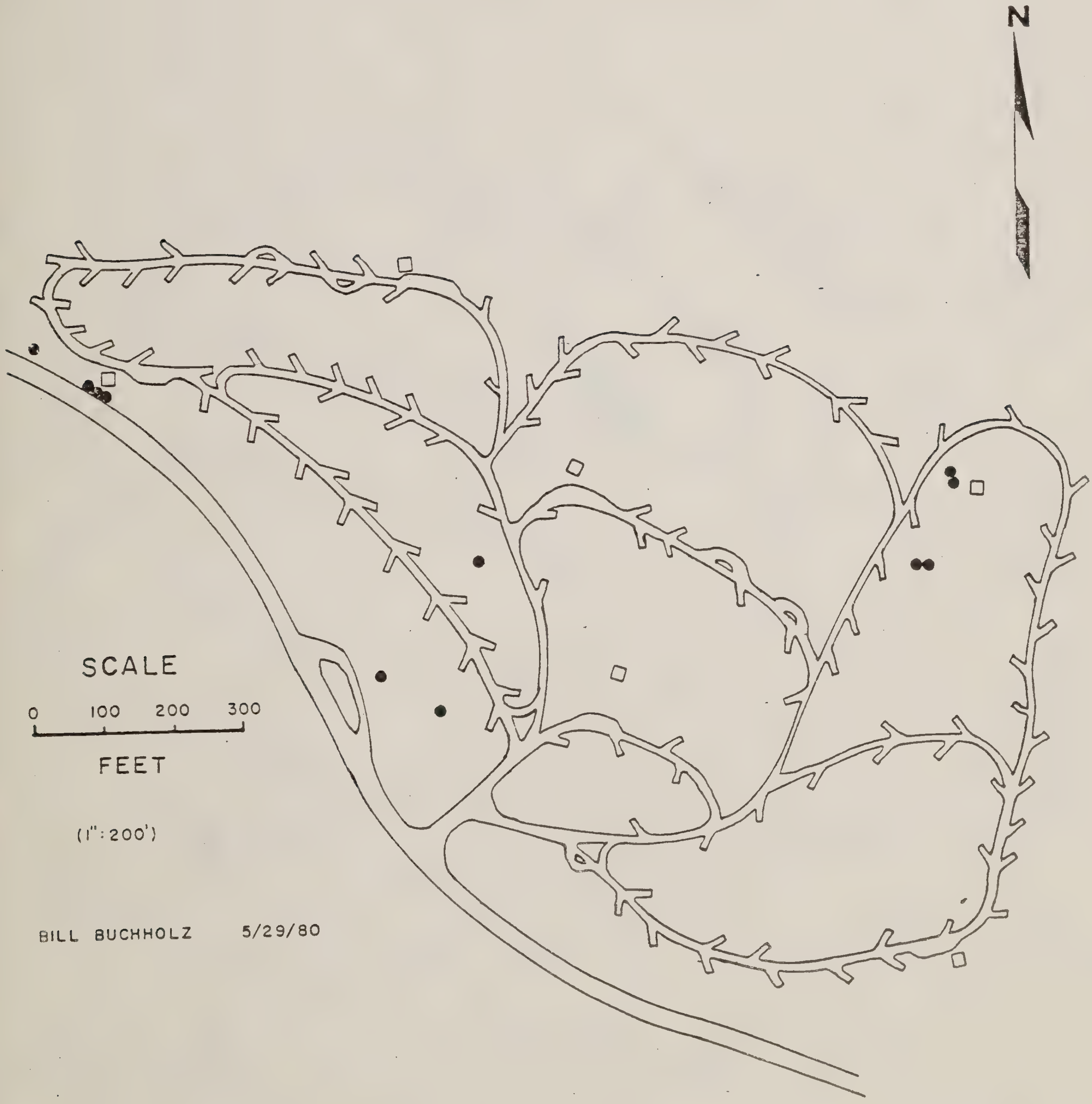
CONFIRMED *FOMES ANNOSUS* ROOT DISEASE CENTER



SUSPECTED *F. ANNOSUS* ROOT DISEASE CENTER

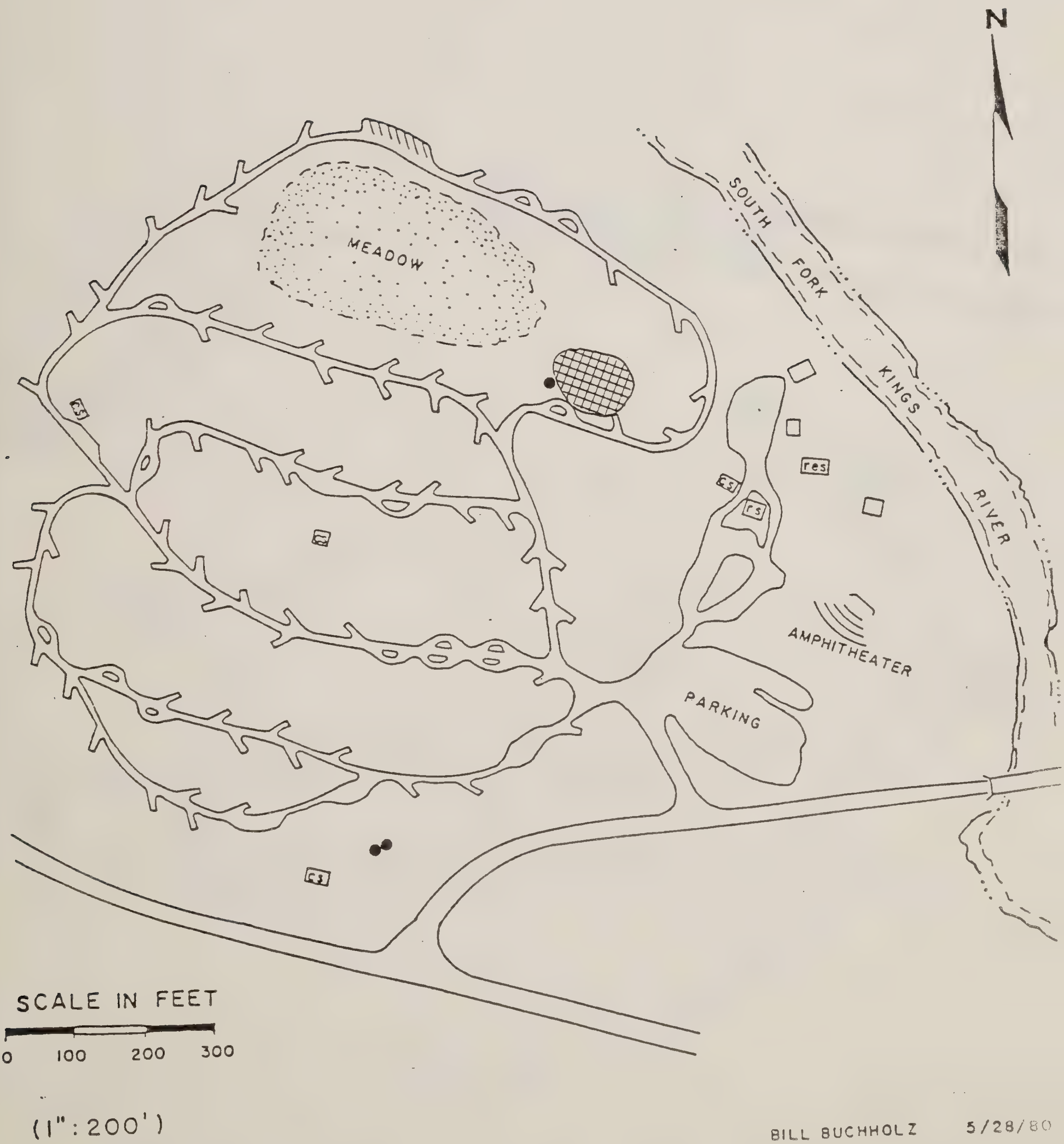
SEQUOIA & KINGS CANYON NATIONAL PARKS

SHEEP CREEK CAMPGROUND
CEDAR GROVE



SEQUOIA AND KINGS CANYON NATIONAL PARKS

SENTINEL CAMPGROUND



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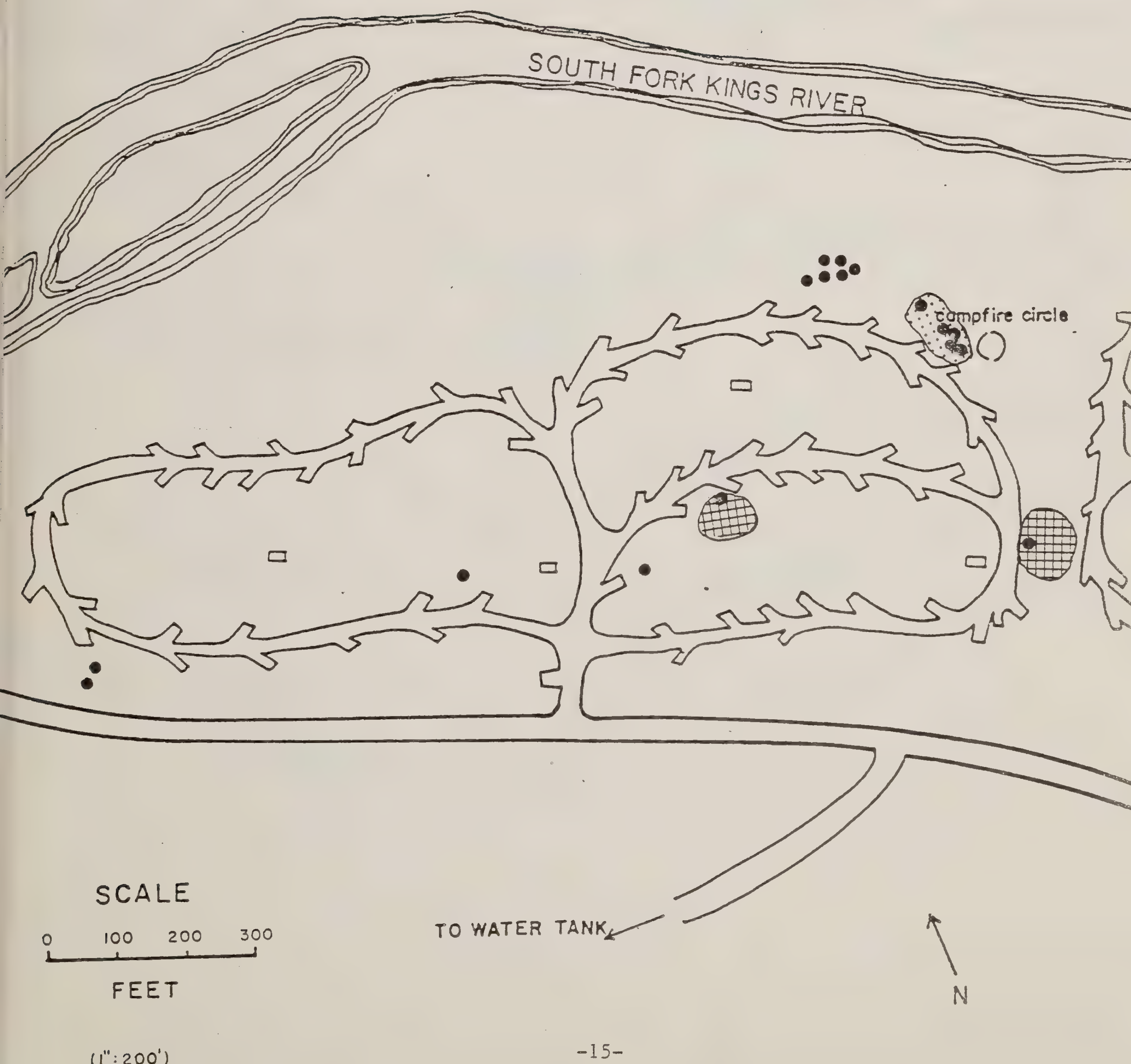
SEQUOIA & KINGS CANYON NATIONAL PARKS

CANYON VIEW CAMPGROUND

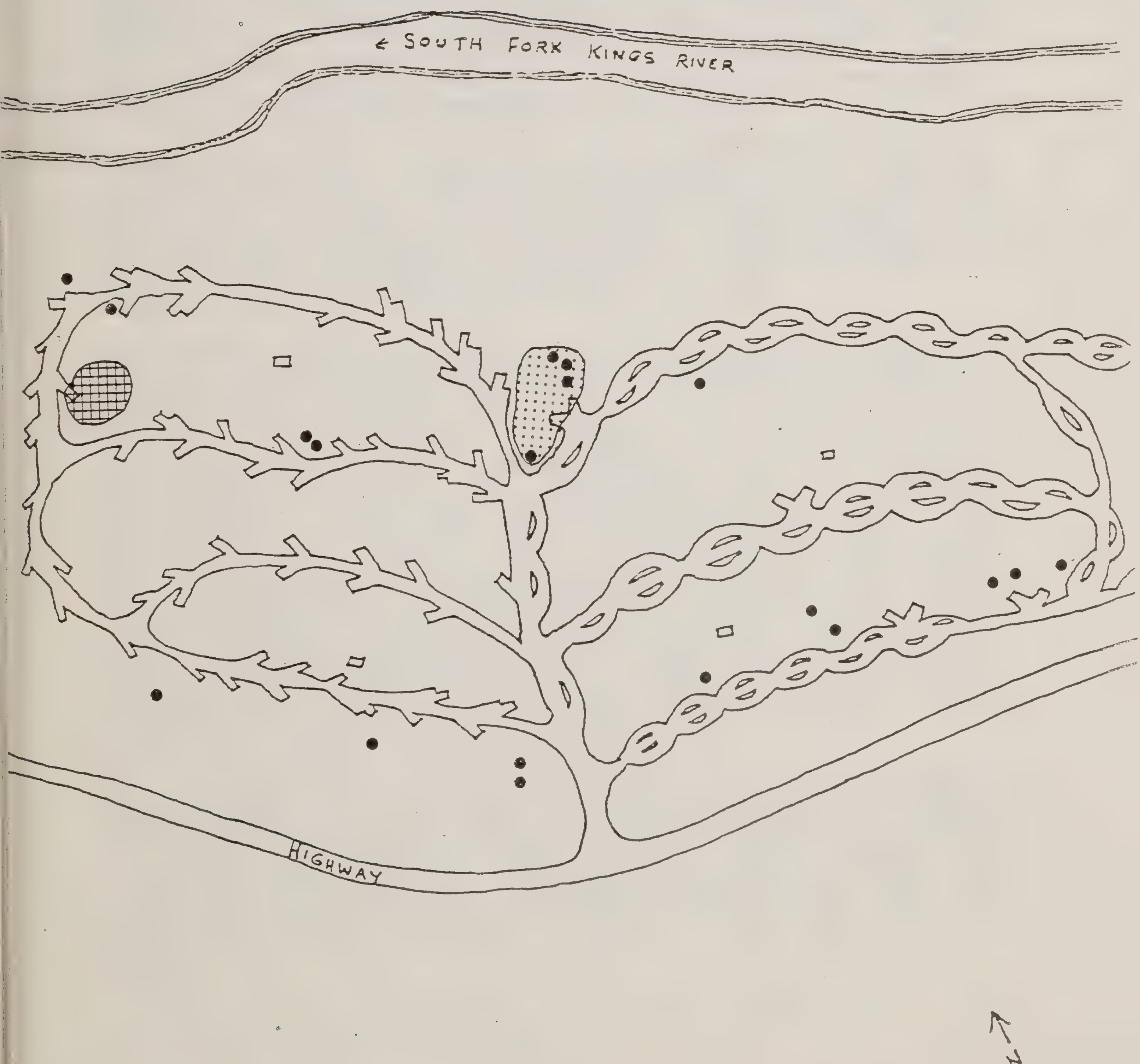
CEDAR GROVE



SEQUOIA & KINGS CANYON NATIONAL PARKS

MORAINE CAMPGROUND

CEDAR GROVE



APPENDIX B

PEST BIOLOGY - CEDAR GROVE

PINE BARK BEETLES

The biologies and habits of the western pine beetle, *Dendroctonus brevicomis*, Jeffrey pine beetle, *D. jeffreyi*, and mountain pine beetle, *D. ponderosae*, are similar in many respects. Adult beetles bore galleries under tha bark of standing live trees where the females lay eggs. Usually blue stain fungi are carried on the bodies of the invading beetles so the host is also infected by these organisms. The subsequent development of the fungus and young beetle broods usually kills the host.

Prospective host trees can resist bark beetle invasion with pitch and resin which is somewhat toxic to the beetles. Characteristics globs of pitch and boring dust (pitch tubes) are often found on attacked pine because the beetles push this material out of their tunnels as they struggle to overcome the tree's resistance. Healthy trees are able to produce large amounts of pitch to contest beetle entries, but diseased, injured, or drought-stressed trees are more likely to succumb.

Bark beetles attacking a tree produce attractants (pheromones) that aggregate more beetles of the same species near a successfully attacked tree. Beetles may land on nearby healthy trees and the overwhelming number of attacks can result in a group of trees being killed. Group kills can sometimes be prevented by vegetation management. The pine most likely to become the center of a bark beetle mortality spot can often be identified by symptoms of low vigor such as a flat-topped or ragged crown with short, tufted foliage. If the "high risk" pine is removed while green, it will increase the vigor of surrounding trees by acting as a light thinning and will offer some protection to pines of the same species within about 20 feet by eliminating the potential center of a mortality spot. Periodic thinning to maintain stocking below "normal" levels will also increase tree vigor and prevent bark beetle attacks and potential mortality groups. There is a strong relationship between the basal area of an aggregation, the subsequent individual tree growth and attacks by pine bark beetles. Treatments which reduce or prevent disease such as dwarf mistletoe and annosus root disease will also prevent some bark beetle attacks.

The biology of pine bark beetles differ mainly in their hosts and number of generations per year. The only host of western pine beetle at Cedar Grove is ponderosa pine. There would be 3 or 4 generations per year, depending on seasonal temperatures. Mountain pine beetle breeds in ponderosa and sugar pine in the campgrounds. It generally has one generation per year. Lodgepole pine is also a host at higher elevations in the park. The Jeffrey pine beetle has a one year life cycle in Jeffrey pine, which is its only host.

FIR ENGRAVER

Scolytus ventralis attacks most true firs in western North America. Attacks can kill tops, patches of cambium along the bole or entire trees ranging from large saplings to old growth. Mortality and top-kill frequently are associated with stress induced by overstocking, drought, root disease, soil compaction, excessive and sudden exposure, heavy dwarf mistletoe infections, and other factors limiting tree health and vigor. Because of the sporadic occurrence of widespread mortality and top-kill, and the presence of brood in living trees, direct control measures are generally impractical. A healthy, vigorously growing stand is the best means of minimizing losses.

Adults fly and attack trees or green fir slash between June and September. Larvae, pupae, and adults overwinter under the bark of infested trees. The life cycle takes one year, rarely two. Pitch tubes are not formed as with pine bark beetles, but attacks are sometimes characterized by boring dust in bark crevices along the trunk and pitch streamers on the mid- and upper-bole. Trees successfully attacked early in the summer may exhibit fading of the foliage by early fall, but those attacked later in the year will not begin to fade until the following spring or summer. The beetles may have emerged by the time the tree fades.

Several other species of Scolytus, along with Pseudohylesinus, may be associated with the fir engraver. These contribute to the damage, but usually are not primary insects. The roundheaded fir borer, Tetropium abietis, is a frequent associate also.

PINE ENGRAVER

Pine engraver beetles, Ips spp., breed either in the tops of all species of living pine trees or in fresh green pine slash. Attacking adults may be found under the bark contructing a typical three- or four-egg gallery from a central nuptial chamber. These galleries run parallel with the wood grain and assume a Y or H pattern. The galleries are kept clear by the adults and consequently the reddish boring dust piles up near the entrance holes. The dust is particularly visible on horizontal host material such as blowdown. On standing trees it catches on bark flakes crevices, and spider webs.

Attacks are made with the coming of warm weather in the spring. A new generation is produced in 6-8 weeks during summer. Thus, several overlapping generations per year may be produced. The winter may be passed in any of the life stages of larvae, pupae, or adults, depending upon species involved. Attacks on live trees are usually limited to trees which are suppressed, or stressed by dwarf mistletoe, root disease, drought or fire. Young pines 2-8 inches dbh and the tops of older trees are the most at risk. This is particularly true of densely stocked groups of trees. Attacks on tops and limbs may preceed or occur simultaneously with attacks by Dendroctonus bark beetles. Outbreaks in standing, healthy trees are sporadic and of short duration, and are often associated with some temporary stress or shock afflicting the host species, such as severe competition or sudden opening of the stand.

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GRAVEL

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Tree killing may occur where green pine slash, which serves as breeding habitat, is left untreated during spring and summer. One approach to minimizing damage is to schedule slash-generating activities such as thinning or dwarf misteltoe broom pruning mostly in the late summer, fall and early winter, when slash has a high probability of drying out before the beetles can complete their development. Green pine slash created during the spring and summer should be treated to prevent the buildup of pine engraver populations. Because pine engravers can complete their development in about a month and a half under ideal conditions, treatment should be carried out soon after cutting to be effective.

The most acceptable methods of slash treatment in high use recreation areas would probably be disposal by chipping or removal from the site. Some methods of slash treatment that might be acceptable in dispersed recreation areas would include lopping and scattering slash in sunny areas to speed its drying out, crushing or mashing slash with heavy equipment to make it unsuitable for pine engraver breeding or piling and burning the slash within a month of cutting. Broadcast burning the slash might work if it could be done while the slash was green and without damaging the residual stand. Another method which might work is to pile slash in a sunny area and tightly cover the pile with clear plastic. If the temperature under the bark of slash in all parts of the pile reaches 120°F, all brood currently in the pile will be killed; lower temperatures are not effective. Even when this method is successful, however, it will not prevent reinfestation of treated slash piles.

CALIFORNIA FLATHEADED BORER

Most species of pine are hosts for the California flatheaded borer, *Melanophila californica*. Females lay eggs in bark crevices of host trees during summer. Larvae hatch and bore into the cambium. They feed for a period of a few months to 4 years, depending on host vigor. The small larvae cut thin mines in a serpentine pattern across the cambium.

If the host is relatively vigorous and the small larvae are not abundant, the larvae will die and their mines will be callused over. Larval mines and host scar tissue can block conductive tissues and cause general tree weakening. If the tree is overcome, small larvae develop rapidly and kill the cambium. They pupate in the bark and emerge as adults in as little as one year after the tree was attacked, although some larvae survive in green trees for several years.

The California flatheaded borer commonly kills pines growing on rocky slopes, in fringe-type stands, or in other situations where soil moisture is insufficient for normal tree growth. It is often found in trees weakened by dwarf mistletoe, root disease or old age. This species is of primary importance in weakening trees and causing them to become susceptible to pine bark beetles.

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FLATHEADED BORER

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RED TURPENTINE BEETLE

Adults of the red turpentine beetle, Dendroctonus valens, attack all species of pines in California. They lay eggs in cave-like galleries between the bark and wood on the lower bole. The larvae that hatch at each attack point destroy from about 0.1 to 1 square foot of cambium. Attacks occur throughout warm weather. The number of generations varies from one every 2 years at the coldest portions of its range to 2 or 3 per year in the warmest.

Red turpentine beetles normally attack injured, weakened, or dying trees, and freshly cut logs and stumps. Fire scorched trees are frequently attacked. A few isolated attacks will not usually kill a tree but repeated attacks may weaken it enough to be susceptible to pine bark beetles. Trees infected with root disease often show heavy attack by this beetle.

ANNOSUS ROOT DISEASE

Fomes annosus attacks most conifers in California. The fungus spreads long distances above ground by air-borne spores; these are produced by conks in decayed stumps, under the bark of dead trees, or under the duff at the root collar. The spores land on freshly-cut stump surfaces or on wounds in living trees, germinate, and colonize the exposed wood.

Once established in a stump or tree, the fungus grows into and through the host roots until it contacts the roots of adjacent trees, where it infects and invades their root systems. In this way, F. annosus spreads from stumps or dead trees into the roots of living trees in an enlarging infection center. The fungus may also spread through roots into adjacent fresh stumps or recently-dead trees, but only if they are not already colonized or decayed by other fungi.

F. annosus can remain viable in old infected roots or stumps for as long as 50 years. Infection centers usually continue to enlarge until they reach natural barriers such as openings or groups of non-host plants. Young conifers established within infection centers often die shortly after their roots contact infected roots in the soil.

This root pathogen affects pines and true firs in different ways. It kills pines relatively quickly without causing extensive decay. The fungus spreads through the inner bark and sapwood of the pine root systems, killing these tissues; within 2-6 years it reaches the root crown and girdles the tree. By contrast, true firs are seldom directly killed. The fungus kills small fir roots and spreads into the heartwood of the larger roots, and then into the lower bole of the host, where it causes a butt rot. Vigor and merchantable volume are reduced. If the fir does die it is usually the combined result of root disease and insect attack.

Generally, firs growing within pine disease centers are highly susceptible to annosus infection, while pines adjacent to infected fir stumps usually escape attack. Thus, large fir infection centers can be revegetated by selecting for or planting pines.

DWARF MISTLETOES

Dwarf mistletoes are parasitic, flowering plants, in the genus *Arceuthobium*, that can survive only on a living host. They obtain all their water, nutrients, and minerals from the host.

The parasite spreads by means of seed. In the fall the fruit ripens, detaches from the aerial shoot, and the seed is forcibly discharged. The seed is covered with a sticky substance, and adheres to whatever it contacts. When a seed lands in the crown of a tree, it may adhere to a needle or twig, where it will remain throughout the winter. The following spring it may germinate and penetrate into the tree. For the next two to four years, the parasite will grow within the twig and develop a root-like system in the inner bark and outer sapwood. It will then develop aerial shoots that produce seed in another two to four years.

The spread of dwarf mistletoe is limited to the distance traveled by the seed, which from overstory to understory is usually 20 to 60 feet; with the aid of wind, the seed may occasionally be carried as far as 100 feet. A rule of thumb is that dwarf mistletoe can spread a horizontal distance equal to the height of the plant in the infected tree. Because of the various limits to spread, the actual spread rate through an even-aged stand is usually one to two feet per year.

Some dwarf mistletoes parasitize only one species of conifer. Others may occur on three or four closely-related species, but only rarely do they cross-infect from one conifer genus to another. Because of their specificity, the dwarf mistletoe species can be identified by the hosts they infect.

The impact of dwarf mistletoe varies on different species and is significantly influenced by tree vigor. For example, the impact of dwarf mistletoe is less on true fir than on pines; its impact on vigorously-growing trees is less than on slow-growing or stagnated ones. Nevertheless, the dwarf mistletoes are the most serious forest disease agents in much of the West, causing extensive growth losses and predisposing conifers to attack by insects and other pathogens.

TRUE MISTLETOES

Like the dwarf mistletoes, the true mistletoes (genus *Phoradendron*) are flowering plants that require a living host. They are generally less demanding of their hosts than the dwarf mistletoes, yet can be serious pests where individual trees are of high value, as in yards, parks, and campgrounds.

Some species of true mistletoe grow on only a single genus of tree; others occur on a wide range of hardwoods. Although they are completely parasitic, they manufacture many of their nutrients by photosynthesis and usually require only water and minerals from their hosts. However, if the green aerial shoots of the mistletoe are removed, the root system of the parasite can utilize the host's nutrients and remain alive within an infected branch for many years.

True mistletoe infections are spread mainly by birds - including robins, bluebirds, thrushes, and cedar waxwings - that feed on the berries. Birds digest the pulp of the berries and excrete the living seeds, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect the host tissues.

Young or small trees are seldom infected by leafy mistletoe. In nearly all cases, initial infection occurs on larger or older trees because birds prefer to perch in their tops. Severe buildup of mistletoe often occurs in an already-infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

Trees heavily infected by mistletoe are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attack by insects and often succumb during drought or other periods of stress. Branches heavily-laden with mistletoe often break during storms or high winds, and trunk swellings may provide an entrance point for decay fungi, increasing the hazard to people and property in campgrounds and other developed sites.

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THE FOREST SERVICE OF THE U.S. DEPARTMENT OF AGRICULTURE is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through management of the National Forests and National Grasslands, cooperation with the States and private forest owners, and forestry research, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

THE GOAL OF FOREST PEST MANAGEMENT is to reduce pest-caused damage and losses on all forests and rangelands to levels commensurate with management objectives. The Forest Pest Management Staff provides leadership to forest land owners in dealing with pest problems effectively, while minimizing adverse effects on man and his environment.